**CARTILAGE AND BONE TISSUE**

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H.I.R Chapter 7

**CARTILAGE**

Cartilage is one form of connective tissue that accentuates the intercellular (extracellular) matrix. As with most connective tissues, the cartilage matrix is produced and maintained by *fixed cells* which are known as *chondroblasts* and *chondrocytes,* respectively. *All cartilage is characterized by large round cells surrounded by large amounts of amorphous extracellular matrix.* The predominant extracellular fiber determines the specific type of cartilage. Because of the nature of the constituent components of the ground substance and the embedded fibers, the matrix is "strong" but somewhat deformable. Hyaline cartilage normally is found in the trachea, costal cartilage of ribs, developing long bones of fetus, and articular cartilage of the synovial joints where flexibility, compressiblity and slipperiness is needed. .

**HYALINE CARTILAGE**

[**[MCO 0060]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0060&type=ax&section=epithelium) Trachea & Esophagus, Rodent [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0060&type=jv&section=epithelium) HIR-*frame 358-362*

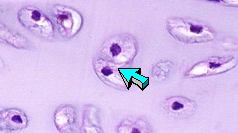
 (Hylaine Cartilage and Perichondrium)

\*\*\*Matrix with Proteoglycans (aggrecan aggregates)

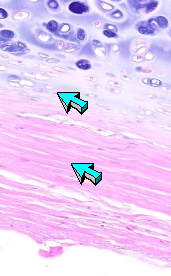
 (Chondrogenic layer = apposition growth)

 (Territorial Matrix–darker, Interterritorial Matrix–Lighter)

[**[MCW 021]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf3_MCW021&type=ax&section=epithelium) Trachea, H&E [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf3_MCW021&type=jv&section=epithelium)

 (Isogenous Group = interstitial growth)

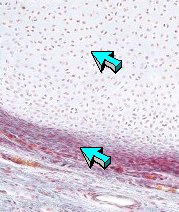
[**[SL 035]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf4_SL035&type=ax&section=epithelium) Trachea [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf4_SL035&type=jv&section=epithelium)

 (fibrous layer and chondrogenic layer of perichondrium)

**Hyaline cartilage** forms an incomplete red staining ring (**MCO 0060,** blue staining in the other two slides) within the wall of the round trachea. The holes or openings within the cartilage ring are the lacunae (lakes) containing chondrocytes. The chondrocytes are shrunken during processing and are seen as dark masses in the center of the open lacunae. The red (blue) staining material between the lacunae is the cartilage matrix. This contains collagenous fibrils which are masked by hyaline ground substance. The capsule is the more basophilic staining matrix recently laid down adjacent to the chondrocytes. It is basophilic due to its higher concentrations of chondroitin sulfates. The interterritorial matrix is the lighter-staining matrix farther away, between the cartilage cells. The difference in staining properties is usually only seen in cartilage that is still growing and not in that which is being maintained (in the mature or adult human). The perichondrium is the layer of flattened connective tissue cells which encloses the cartilage. It has an outer, fibrous layer and an inner, chondrogenic layer. The cells of the chondrogenic layer are more rounded instead of flattened as in the fibrous layer. The perichondrium is separated from the cartilage by shrinkage artifact.

[**[MCO 0017]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0017&type=ax&section=cartilageand%20bone)Fetal Finger, Early Endochond. Ossif. [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0017&type=jv&section=cartilageand%20bone)

HIR-*frames 398-399, 362, 405-408*

 (Perichondrium and Hylaine cartilage model)

[**[MCO 0617]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0617&type=ax&section=cartilageand%20bone)Fetal Finger, Later Endochond. Ossif.[**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0617&type=jv&section=cartilageand%20bone)

[**[LH 0026]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf1_LH0026&type=ax&section=cartilageand%20bone) Fetal Finger [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf1_LH0026&type=jv&section=cartilageand%20bone)

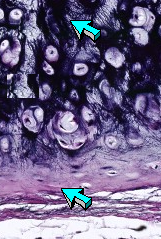
[**[SL 004]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf4_SL004&type=ax&section=cartilageand%20bone) Fetal Digit (Endochondrol Oss.) [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf4_SL004&type=jv&section=cartilageand%20bone)

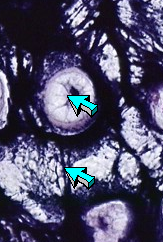
In these slides, hyaline cartilage serves as a template for long bone formation. The light blue staining tissue is the hyaline cartilage precursor model of the phalanges. Use this slide to distinguish between appositional growth and interstitial growth of cartilage. Interstitial growth is represented by isogenous groups ("cell nest") of chondroblasts. These cell nests consist of groups of chondroblasts(2,4 or 8 cells) closely clustered together deep within the mass of cartilage. These cells are the progeny of a single chondroblast. Appositional growth occurs at the edge of the cartilage mass by mitosis in the chondrogenic layer of the perichondrium. This can be recognized by the larger, rounder cells immediately subjacent to the fibrous (flattened fibroblasts) layer of the perichondrium. The hyaline cartilage model of long bones permits the fetus to bend and flex more easily during the birth process.

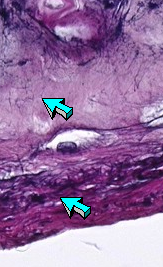
In most of these slides, a forming synovial joint is also being formed. Look for the clear synovial cavity between the cartilage shapes, the forming articular surfaces lacking perichondrium, and the forming connective tissue capsule which closes the cavity between the two cartilage models of long bone. What are the five structural characteristics of any synovial joint?

**ELASTIC CARTILAGE**

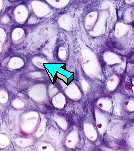
[**[MCO 0012]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0012&type=ax&section=cartilageand%20bone)Elastic Cartilage, Epiglottis [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0012&type=jv&section=cartilageand%20bone) HIR-*frames 365-367*

 (Elastic cartilage and Perichondrium)

 (Elastic Fibers and Chondrocyte)

 (Fibrous and Chondrogenic layer of perichondrium)

[**[SL 065]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf4_SL065&type=ax&section=cartilageand%20bone) Epiglottis (Elastic Cartilage) [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf4_SL065&type=jv&section=cartilageand%20bone)

 (Elastic Cartilage)

This long organ has a broad base at one end and tapers to a point at the other end. Running down the middle from one end to the other is a darkly stained rod of elastic cartilage. **Elastic cartilage** is similar to hyaline cartilage with elastic fibers in the matrix. The chondrocytes lie within the diagnostic large oval-shaped lacunae (clear). The matrix between the cells is quite dark due to masses of darkly stained elastic fibers. The VIH stain is specific for the elastic fibers and stains them black. In H & E stained elastic cartilage, the elastic fibers are quite difficult to visualize. The stretch and rebound characteristic of the elastic fibers allows the organ containing elastic cartilage to spring back to its original shape and position. This is what occurs in the epiglottis, external pina of the ear and auditory tubes.

**FIBROCARTILAGE**

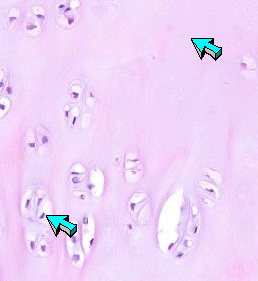
[**[SL 093]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf4_SL093&type=ax&section=cartilageand%20bone) Intervertebral Disc [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf4_SL093&type=jv&section=cartilageand%20bone) HIR-*frames 368, 369*

 (Annulous fibrosis = Fibrocartilage and Nucleus pulposis)

\*\*\*As you go toward the periphery the fibrous cartilage starts to turn into dense regular connective tissue

 (Fibrous Cartilage and Collagen type I Fibers)

[**[LH 0020]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf1_LH0020&type=ax&section=cartilageand%20bone) Symphysis Pubis [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf1_LH0020&type=jv&section=cartilageand%20bone)

 (Fibrous Cartilage-light stain fiber & Isogenous groups)

**Fibrocartilage** appears like dense connective tissue with cartilage cells. There are large round chondrocytes embedded in a matrix full of large bundles of collagenous fibers. The ground substance is greatly reduced due to the great numbers of collagen fibers present. It is found where cartilage is subject to pressure, such as in the intervertebral discs (**SL 093**) between the vertebrae, pubic symphysis or where tendons or ligaments attach to bone. This section comes from the intervertebral disc between two vertebrae. The chondrocytes retain their characteristic oval or round shape to distinguish it from dense irregular or regular connective tissue. This cartilage tissue is *avascular* like the other two types of cartilage. The slightly pinker staining material at the edges is bone tissue from the adjacent vertebrae. Be sure to see the demonstration of the developing fetal vertebrae and intervertebral disc.

The fibrocartilage is located between the two coxal bones of the pelvis in the pubic symphysis (**LH 0020**). The darker staining marrow marks the bones and the pinker stained fibrocartilage has the characteristic tightly packed, wavy, bundles of collagen fibers with large round cells present. Be able to describe the structural characteristics of each type of cartilage.

**BONE**

There are 5 types of cells in bone tissue: (1) osteoblasts, which form the bone tissue; (2) osteocytes which maintain the bone as they lie within lacunae in the bone substance, and (3) osteoclasts which resorb bone; (4) bone lining cells that separate the bone tissue from the rest of the body and (5) osteoprogenitor cells which can not be readily identified. Bone is a vascular and dynamic tissue which undergoes constant remodeling through continuous resorption and formation of bone tissue. Osteocytes and bone tissue are periodically removed by the remodeling process. Osteocytes have processes which extend to the perivascular space to bring in nutrients. The external surface of bone tissue is covered by periosteum which acts and looks similar to cartilage's perichondrium. The periosteum has two layers, an outer fibrous layer and an inner osteogenic layer. There are Sharpey's fibers or perforating fibers, which are bundles of collagen fibers that enter the bone matrix from the periosteum. The internal surface of bone tissue is covered by a single-cell-thick layer called the endosteum.

The bone matrix is composed of an organic and an inorganic component. Collagen makes up 90% of the organic component of bone which accounts for approximately 30 - 40% of bone substance. The other 60 - 75% of bone is inorganic in nature and is predominantly calcium phosphate and carbonate in the form of hydroxyapatite crystals positioned between the collagen fibers. This combination of collagen fibers and the hydroxyapatite crystals is like using straw in clay to make bricks. This gives bone great strength with resistance to breakage or deformation. Because of the presence of the inorganic component, bone tissue contains only a small amount of ground substance.

Bones, like a femur, are grossly divided into compact (dense) and spongy (trabecular) bone. Compact bone forms the very dense outer walls (cortex or cortical bone) of the shafts in long bones.

*Spongy bone* is made of a fine meshwork of spicules of bone called trabeculae. Spongy bone is found inside the shafts of bones. The space between the spicules is filled with bone marrow.

*Compact bone* is vascularized via Haversian systems (Osteons). Nutrient vessels enter from the external aspect of the bone via the periosteum, pass into the bone and give off vessels which run the length of the Haversian system. Volkmann's canals are diagonally-oriented channels containing blood vessels which supply the Haversian canals. The Volkmann's canals do not have layers of concentric lamellae of bone which is characteristic of the Haversian systems.

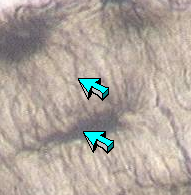
The Haversian system, (osteon) the basic structural and functional unit of compact bone, consists of the (1) Haversian canal which contains blood vessels and nerves, and (2) concentric lamellae of collagen fibers. In cross section, these lamellae appear as concentric rings around the Haversian canal. **These lamellae of collagen can only be seen in polarized light.** Lacunae, which contain the osteocytes, are also arranged concentrically around the Haversian canal within the lamellae.

[**[MCO 0014]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0014&type=ax&section=cartilageand%20bone)Compact bone, Dry [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0014&type=jv&section=cartilageand%20bone) HIR-*frame 376*

 (Osteon and Haversian canal)

\*\*\*Bone lining cells around the Haversian Canal

 (Cement Line and Osteocytes)

 (Lacunae and Caniculi – also calcified matrix)

 (Interstitial Lamellae 🡪 remnants of old osteons)

\*\*\*Lamellar bone-🡪 There is internal remodeling going on

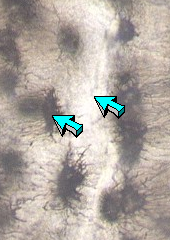
 (Volkmann’s canal) \*\*\*No rings of cells = no osteon

\*\*\*Bone lining cells around the Volkmann’s Canal

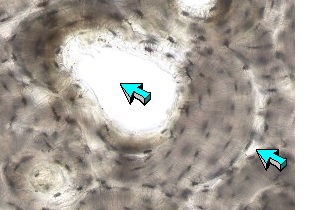
 (Closing Cone 🡪 New layers of osteocytes around the outside)

 (resorption Cone = no new cells around it 🡪 the bone is being chewed away)

 (Volkman’s canal)

 (Osteocyte & cement line) \*\*\*Caniculi not cross cement line)

[**[SL 002]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf4_SL002&type=ax&section=cartilageand%20bone) Bone (Ground) [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf4_SL002&type=jv&section=cartilageand%20bone)

(Developing Osteon and cement ine)

\*\*\*Can not really see the calcification site but this is calcified

[**[UW 2015]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf7_UW2015&type=ax&section=cartilageand%20bone) Bone (Ground) [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf7_UW2015&type=jv&section=cartilageand%20bone)

 (Circumferential Lamellae)

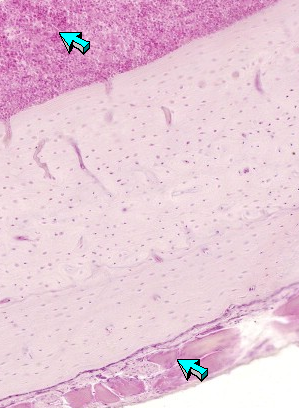
These slides are both cross and longitudinal sections of ground bone. They are prepared by grinding down a thin piece of dried bone until it can be viewed under the microscope. The Haversian systems can be clearly seen in this type of preparation. The spaces of the ground bone (Haversian and Volkmann canals, lacunae, and canaliculi) are dark due to being filled with Indian ink (or clear where the ink did not penetrate).

In cross section, the large dark spaces are the Haversian Canals (central) containing blood vessels at the center of the Haversian System. Osteocytes occupy the dark lentiform lacunae arranged in several concentric rings around the central canal. Lamellae of collagen fibers are layered in between the rings of osteocytes, but they can not be seen in these sections without polarized light. Canaliculi are thin dark threads running from the lacunae of one ring to the lacunae of adjacent ring of cells. The canaliculi are the fine tunnels containing the osteocyte cell processes which communicate with adjacent cells. In the longitudinal section, Haversian systems usually are 3-5mm in length. Numerous osteons are packed end-to-end and side-to-side to form the compact bone.

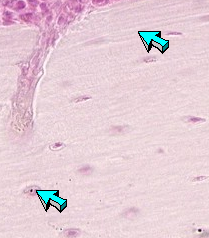
Cement lines are refractile lines (light) at the outermost extent of individual osteons. The cement line has very few collagen fibers in it but it is still highly calcified. The interstitial lamellae, which are remnants of former osteons, are seen as incomplete parts of Haversian systems between the complete Haversian systems. The layering of lacunae is still seen, but there is no central canal with which these layers are associated. Volkmann's canals are typically vessels within tunnels running perpendicularly to the bone surface. They are characterized by the lack of concentric rings of osteocytes around the vessel.

**Make sure to look for the same structures in the longitudinal section.**

[**[MCO 0018]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0018&type=ax&section=cartilageand%20bone) Compact Bone, Decalcified [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0018&type=jv&section=cartilageand%20bone) HIR-*frame 373*

 (Muscle and Bone marrow)

 (Blood vessel from bone marrow = Volmann’s canal)

 (Endosteum lays down inner circumferential lamellae) and Osteocyte) 🡪 also a blood vessel (Volkmann’s canal)

 (Endosteum cells)

\*\*\*Endosteum hard to differentiate from inner circumferential lamellae

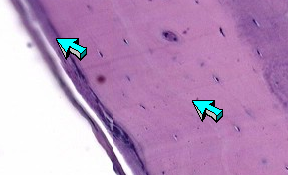
\*\*\*Endosteum kinda looks like simple squamous epithelium

 (Periosteum lays down Outer circumferential Lamellae)

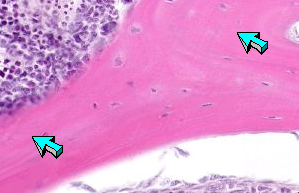
(Osteon)

[**[UW2016]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf7_UW2016&type=ax&section=cartilageand%20bone) Decalcified Bone & Marrow [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf7_UW2016&type=jv&section=cartilageand%20bone)

 (Endosteal cell)

 (outer circumferential lamellae & Periosteum)

**[**[**UW 2020]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf7_UW2020&type=ax&section=cartilageand%20bone) Calvaria, Monkey [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf7_UW2020&type=jv&section=cartilageand%20bone)

 (Osteon and Trabecular Packet)

 (Trabecular Packet and Endosteum)

In the cross section of decalcified bone, look to visualize the cellular and organic elements of bone. Look for the fibrous and osteogenic layers of the periosteum. In some slide, the periosteum is artifactually separated from the dense cortical bone. *Sharpey's fibers are not readily visible in these slides, see demonstration.* The endosteum is represented by a single layer of thin flat nuclei on the surface of the marrow cavity. You have to look carefully to separate them from the round hemopoietic cells of the red bone marrow. In the compact bone, identify the osteocytes and their cell process in the canaliculi. Osteons can be seen in **UW 2020**. In **MCO 0018***,* look for the outer circumferential lamellae adjacent to the periosteum. A thinner layer of inner circumferential lamellae can be seen adjacent to the endosteum. These lamellae are formed from the periosteum and endosteum, respectively. Osteons are the basic functional unit of dense bone tissue. Trabecular packets are the functional unit in the structure of trabecula in spongy bone. The larger trabecula may also have osteons present. Make sure to look for the same structures in the longitudinal section.